Multidimensional Representation of Decision-making in Chronic Schizophrenics

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We administered all paired comparisons of eight gambling stimuli to samples of inpatient schizophrenics, outpatient schizophrenics, and a comparison group of first-degree relatives. A matrix of pairwise preferences was elicited from each subject, and decomposed into a binary matrix indicating stimulus choice, and an unsigned dissimilarity matrix representing strength of preference. These matrices were analyzed using maximum likelihood multidimensional scaling methods, resulting in a representation of subjects and stimuli in an n-dimensional decision space. Results suggest that choice behavior of all groups was determined almost exclusively by the expected value of the stimuli, with no significant differences among the groups. Strength of preference was influenced by expected value for only the comparison group, with a much larger unsystematic component among the schizophrenic groups.

The construct of decision-making competence has assumed an important role in clinical psychology and mental health law. Determination of competence is a focus of forensic evaluations in the criminal justice system (e.g., competence to stand trial or waive constitutional rights) and in medical settings (e.g., competence to consent to research or refuse medical treatments). Little empirical research has attempted to identify the specific cognitive abilities required for competent decision-making.

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Most theorists have recommended that in order to be considered a competent decision-maker, a person must be able to integrate information in a manner logically consistent with personal values (Appelbaum & Grisso, 1988). Difficulties in the operationalization of constructs such as logical consistency have limited assessments of competence to constructs that are less theoretically appropriate but more easily measured. These include subjects’ ability to recall pertinent information (e.g., Lidz et al., 1984), explain the basis for their decision (Appelbaum, Mirkin, & Bateman, 1981), or conform to the decisions of a hypothetical “reasonable person” (Weithorn & Campbell, 1982).

The reasonable person standard is especially problematic because experimental research has shown that the decision-making of normal subjects often deviates from optimal or rational standards (e.g., Abelson & Levi, 1985; Kahnemam, Slovic, & Tversky, 1982; Simon, 1986). The current article describes the application of experimental and statistical methods developed for analysis of decision-making behavior in normal subjects to clinical populations. In particular, we employ scaling models that permit inferences of decision-making process without reliance on introspection, verbal report, or comparison to a hypothetical reasonable person.

The few previous empirical studies of decision-making in clinical populations have relied primarily on self-reported decision-making in hypothetical situations (Costello, 1983; Radford, Mann, & Kalucy, 1986). Only two studies have utilized experimental paradigms to assess decision-making competence. Huq, Garety, and Hemsley, (1988) compared ability to make probability judgments in delusional schizophrenic subjects and non-delusional psychiatric patients. Delusional schizophrenic subjects required significantly less information before they were willing to make a decision, but expressed significantly more confidence in the decisions they rendered.

In addition, our laboratory recently reported the results of a paired comparison gambling task analyzed using traditional linear and least squares estimation models (Rosenfeld, Turkheimer & Gardner, 1992). In these analyses, chronic schizophrenic inpatients were less able to weigh alternatives consistently than outpatient schizophrenics or comparison subjects. Wechsler Adult Intelligence Scale - Revised (WAIS-R, Wechsler, 1981) Vocabulary subtest was the strongest predictor of decision-making ability in outpatient and comparison subjects, but not in the inpatient sample, for whom degree of psychiatric symptomatology was the strongest predictor.

The complexities of assessing decision-making ability in psychiatric populations may be better addressed using more advanced forms of statistical analysis. Multidimensional scaling (MDS) models of decision-
making offer several advantages over traditional clinical and psychometric assessments. First, they are based on subject behavior in a forced-choice paired-comparison task, independent of introspection and verbal report. Second, the maximum likelihood estimation procedures that form the basis of the methods result in goodness-of-fit indices that can be used to describe the congruence of subject performance with a particular decision model, and which in addition can be transformed to a chi-square or AIC statistic suitable for hypothesis testing. Finally, the methods allow the complex decision-making task to be decomposed into more basic cognitive components.

**Method**

Subjects included 40 involuntarily committed chronic schizophrenic inpatients, 32 chronic schizophrenic outpatients, and 33 siblings or parents of these patients (22 of inpatients and 11 of outpatients). The inpatient sample, described in detail in a previous article (Rosenfeld et al., 1992), was drawn from a state hospital in central Virginia. All patients had been hospitalized for a minimum of six months, were diagnosed with schizophrenia or schizoaffective disorder (with no concomitant diagnosis of an organic brain disorder or mental retardation), and had been committed to the hospital on an involuntary civil status.

The outpatient sample was recruited from two regional mental health centers in central Virginia. Subjects in this group had been discharged from the hospital no less than six months previously, and carried a diagnosis of schizophrenia or schizoaffective disorder with no concomitant diagnosis of an organic brain disorder or mental retardation.

Family members of these two groups of schizophrenic subjects who were currently living in Virginia and the metropolitan Washington, D.C. area were contacted (with the permission of the subject) and offered participation in the study. The comparison group was chosen to match subjects as closely as possible on variables such as socio-economic status, pre-morbid intellectual functioning, and environmental and genetic factors (Chapman & Chapman, 1973). This comparison group, therefore, comprised a sample of non-mentally ill subjects who were genetically and socio-economically similar to the inpatient sample, but without the presence (or history) of manifest symptoms of mental disorder; thereby allowing more direct elucidation of the impact of clinical symptoms on decision-making. Comparison subjects were included in the study if they consented to participate and had no present or past symptoms of mental disorder or psychiatric treatment for a psychotic illness.
No subjects were excluded from participation on the basis of their level of functioning, although several inpatient subjects were unable to complete the testing procedure, and were omitted.

**Decision-making Stimuli**

The experimental stimuli comprised all 28 pairs of eight two-outcome gambles, presented using a procedure developed by Tester, Gardner, and Wilfong (1987) and analogous to those described by past researchers (e.g., Payne, 1975; Slovic & Lichtenstein, 1968). Two levels of probability of winning and losing (0.6/0.4 and 0.4/0.6), two amounts to be won (5 and 3), and two amounts to be lost (5 and 3) were combined to form eight stimuli. The probabilities and amounts to be won or lost were chosen to form a set of stimuli with roughly equal differences in expected values (rather than allow paired comparisons with either large or nonexistent differences in expected value). Pairs of stimuli were represented by two pie diagrams displayed on a computer monitor (Figure 1).

![Figure 1](image.jpg)

*Figure 1*
Paired comparison gambling program (actual display in color).
Each stimulus was divided into two parts, with the upper portion of the pie colored green and labeled “win” and the lower portion colored red and labeled “lose.” Above and below the stimulus were boxes containing green and red circles, which indicated the number of points to be won or lost on each stimulus. At the bottom of the screen a large two-headed arrow was divided into two equal parts and labeled “strongly prefer” at each end and “somewhat prefer” across the middle. A mouse-controlled cursor enabled subjects to indicate the stimulus they preferred and the strength of their preference.

Procedure

Subjects were introduced to the gambling procedure with a prepared script and five practice trials. Subjects were questioned during the practice trials to establish whether they understood the task and were capable of performing the necessary manipulations. Subjects were informed that they would receive payment commensurate with the number of points won in the procedure, and then presented with the 28 pairs of the eight stimuli, randomized as to order of presentation and position on the screen. Following each choice, the computer randomly “played” the stimulus chosen by the subject, providing immediate feedback as to the result of their decision.

Data generated from the decision-making task formed a symmetric matrix in which the sign of each entry indicated whether the row or column stimulus was chosen, and the absolute value of each entry represented the distance the cursor was moved from the center of the screen, indicating strength of preference. Each subject’s matrix was decomposed into the scalar product of two matrices, a choice matrix containing signed binary entries, and a dissimilarity matrix containing positive integers representing strength of preference.

Statistical Analyses

The binary choice matrices were analyzed using a binary maximum likelihood multidimensional scaling (MDS) model developed by DeSarbo and colleagues (DeSarbo, DeSoete, & Eliashberg, 1987; DeSarbo, DeSoete, & Jedidi, 1987; DeSarbo, Oliver, & DeSoete, 1986). The latent utility, $U$, of stimulus $j$ for subject $i$ is defined as,
where \( t \) represents a dimension in a \( T \)-dimensional space, \( a_{it} \) is the \( t \)th coordinate of subject \( i \) and \( b_{jt} \) is the \( t \)th coordinate of stimulus \( j \). The observed utility \( V_{ij} \) is equal to,

\[
V_{ij} = U_{ij} + e_{ij}
\]

where \( e \) is normally distributed error with mean 0 and variance 1. Given a choice between two stimuli \( j \) and \( k \), the probability that subject \( i \) will choose stimulus \( j \) is given by,

\[
\Phi \left( \sum_{t=1}^{T} a_{it}(b_{jt} - b_{kt}) \right)
\]

where \( \Phi \) is the cumulative normal distribution. A log likelihood function can be derived from this expression (DeSarbo et al., 1986), which can be maximized in terms of parameters \( a_{it} \) and \( b_{jt} \) for given dimensionality.

Analysis of the dissimilarity matrices was accomplished using another maximum likelihood scaling procedure (MULTISCALE II; Ramsay, 1986). The variation of MULTISCALE we selected places subjects and stimuli in a \( T \)-dimensional space, with the distance \( d_{ijk}^* \) between stimulus \( j \) and stimulus \( k \) for subject \( i \) given by,

\[
d_{ijk}^* = \sqrt{\sum_{t=1}^{T} a_{it}(b_{jt} - b_{kt})^2}
\]

The observed dissimilarity, \( d_{ijk} \), was estimated as,

\[
d_{ijk} = f(\log d_{ijk}^*) + e_{ijk}
\]

where \( f \) represents raising \( d_{ijk}^* \) to the power \( p_r \) and \( e \) is normally distributed error (Ramsay, 1986, p. 28-31).

Both MDS procedures result in a set of estimated subject and stimulus coordinates and a log likelihood value that describes the goodness-of-fit of the model. Log-likelihood was transformed into an AIC statistic that was
used to test for significant improvement in fit between nested models (this test statistic was chosen to derive the most parsimonious model, particularly given the use of an individual differences scaling models). For each set of matrices, we began with a one dimensional model, and proceeded to fit models of increasing dimensionality until the improvement in fit was no longer significant. Interpretation of the resulting n-dimensional solutions was performed by regressing the stimulus coordinates onto the known characteristics of the stimuli (gain, loss, probabilities, interaction effects, and overall expected value of the stimulus, Arabie, Carroll, & DeSarbo, 1987).

**Results**

**Choice Matrices**

A one-dimensional model fit the binary choice matrices for all three subject groups (Table 1). An MDS model was then fit to the combined groups \((N = 105)\), and the resulting log-likelihood statistic compared to the sum of the likelihood estimates for the three individual subject groups (in order to determine whether a single set of stimulus coordinates fit the entire subject pool). The fit of the combined model was not significantly worse, given the gain in degrees of freedom, than the models generated for the individual subject groups (Table 1, next page), so all subsequent analyses were based on the combined data set.

The stimulus coordinates were strongly related to the expected value of the stimuli \((r[N = 8] = .98, p < .0001)\), as revealed by Figure 2 (following Table 1), indicating that subjects based their decisions almost exclusively on the expected value of the stimuli. The location of subject coordinates along this dimension, therefore, provides a measure of the extent to which a subject's choices were based on expected value. No significant differences were found among the three subject groups \((R^2 = .03, F[2,102] = 1.67, p = \text{N.S.})\). Figure 3 displays subject coordinates by group, revealing the roughly equal weighting of expected value across each subject group.
Table 1
Results of Binary Multidimensional Scaling Analyses

<table>
<thead>
<tr>
<th></th>
<th>-2 ll</th>
<th>DF</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inpatients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Dimension</td>
<td>-450.92</td>
<td>46</td>
<td>-548.92</td>
</tr>
<tr>
<td>2-Dimension</td>
<td>-405.71</td>
<td>92</td>
<td>-601.71</td>
</tr>
<tr>
<td><strong>Outpatients</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1-Dimension</td>
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<td>36</td>
<td>-356.61</td>
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<tr>
<td>2-Dimension</td>
<td>-227.23</td>
<td>72</td>
<td>-379.73</td>
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<td><strong>Comparisons</strong></td>
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<td></td>
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<tr>
<td>1-Dimension</td>
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<td>39</td>
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<tr>
<td>2-Dimension</td>
<td>-261.27</td>
<td>78</td>
<td>-425.27</td>
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<td><strong>Model Comparison</strong></td>
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<td>Combined Data Set Model</td>
<td>-1075.32</td>
<td>111</td>
<td>-1297.32</td>
</tr>
<tr>
<td>Sum of Individual Models</td>
<td>-1068.93</td>
<td>121</td>
<td>-1310.93</td>
</tr>
</tbody>
</table>
**Figure 2**
Relationship of expected value to stimuli location (binary solution).

**Figure 3**
Scatterplot of subject coordinates (binary solution).
B. Rosenfeld and E. Turkheimer

Preference Matrices

The MDS procedure revealed that a one-dimensional solution generated the best fit for the preference matrices of the non-mentally ill comparison subjects (Table 2). However, a zero-dimensional model provided the best fit to the preference estimations of both the inpatient and outpatient schizophrenic samples.¹

Expected values of the stimuli were highly correlated with location on the single dimension for comparison subjects ($r[8] = .99, p < .0001$). Expected value was weakly correlated with a one-dimensional solution for outpatient subjects ($r[8] = .31, N.S.$) and uncorrelated with a one-dimensional solution for inpatient subjects ($r[8] = .07, N.S.$). These findings

Table 2
Results of Dissimilarity MDS Analyses

<table>
<thead>
<tr>
<th></th>
<th>-2 ll</th>
<th>DF</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inpatients</strong></td>
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<td></td>
</tr>
<tr>
<td>0-Dimension</td>
<td>-1451.91</td>
<td>40</td>
<td>-1371.91 (Null Model)</td>
</tr>
<tr>
<td>1-Dimension</td>
<td>-1451.92</td>
<td>125</td>
<td>-1201.92</td>
</tr>
<tr>
<td>2-Dimension</td>
<td>-1587.48</td>
<td>171</td>
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<tr>
<td><strong>Outpatients</strong></td>
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<td></td>
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<tr>
<td>0-Dimension</td>
<td>-1478.80</td>
<td>32</td>
<td>-1414.80 (Null Model)</td>
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<td>1-Dimension</td>
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<td>101</td>
<td>-1324.62</td>
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<td>2-Dimension</td>
<td>-1617.12</td>
<td>139</td>
<td>-1339.12</td>
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<tr>
<td><strong>Comparisons</strong></td>
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<td></td>
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<tr>
<td>0-Dimension</td>
<td>-1818.97</td>
<td>33</td>
<td>-1752.97 (Null Model)</td>
</tr>
<tr>
<td>1-Dimension</td>
<td>-1962.72</td>
<td>104</td>
<td>-1754.72</td>
</tr>
<tr>
<td>2-Dimension</td>
<td>-2035.53</td>
<td>143</td>
<td>-1749.53</td>
</tr>
</tbody>
</table>

¹ Multiscale II computes the likelihood of a zero-dimensional model as the sum of the squared dissimilarities. All model comparisons are based on the degree of improvement over this null model, which corresponds to essentially random dissimilarity estimates.
suggest that schizophrenic subjects' preference estimates were composed almost exclusively of unsystematic variance, with little or no relation to the stimulus characteristics.

Discussion

In hospitalized schizophrenic subjects, some elements of decision-making may be compromised while others remain relatively unimpaired. Inpatient schizophrenic subjects were no less capable than outpatient schizophrenic or first degree biological relatives in basing their gambling decisions on the expected value of alternatives. Inpatient subjects, however, were unable to utilize any consistent strategy in estimating the strength of preferences for an alternative, and outpatient schizophrenic subjects demonstrated little ability to do so.

These findings may be the result of specific deficits in schizophrenics' ability to express preference strength, a lack of motivation to perform a non-essential aspect of the task (payment was affected only by optimal stimulus choice), or an inadequate understanding of cursor movement to demonstrate preference strength. Regardless of which of these hypotheses is correct, the results suggest an inverse relationship between severity of illness and ability to estimate preference strength. Inpatient subjects' preference strength (dissimilarity) estimates reflected primarily unsystematic variance, whereas outpatients demonstrated a large proportion of unsystematic variance combined with some influence of expected value, and comparison subjects based their preference estimations primarily on the expected value of stimuli.

Although the failure to demonstrate a significant deficit in the ability of schizophrenic subjects to make gambling decisions is striking, it must be considered in light of the comparison sample of non-mentally ill first degree relatives. Although not phenotypically schizophrenic, these subjects have a similar genetic structure and therefore may share some of the cognitive deficits found in schizophrenic subjects. However, the group differences in the Multiscale solutions found for the preference data support the hypothesis that differences in decision-making abilities do exist between these groups. Furthermore, the use of a sample as similar as possible to the schizophrenic sample, but without the presence of a diagnosable mental illness represent an ideal comparison group because their decision-making abilities are typically unquestioned (even if similar to their mentally ill relatives).

These results also suggest that the study of decision-making may be more accurately and appropriately conducted by decomposing decision-making into its component cognitive processes. While some of these processes may be impeded by the presence of a mental illness (e.g., ability to
express preference strength), others may not (e.g., ability to consistently weigh risks and benefits in making gambling decisions). Additionally, decision-making abilities may change in the face of more complex, or emotionally salient decision contexts. However, with regard to clinical evaluations of decision-making competence, ascertaining which specific areas of decision-making may be impaired is critical to the accurate assessment and remediation of potential cognitive deficits.

Despite the importance of accurately assessing a patient’s capacity to make decisions, the model utilized in this research has practical limitations as an tool for individual assessment. Some psychotic or medically ill patients may be unable to complete a lengthy computer-generated decision-making task. In addition, the relationship between decision-making ability in a gambling task and decision-making regarding more specific decisions such as medical treatments or hospitalization remains unknown and requires further investigation. Practical limitations notwithstanding, paired comparison models of decision-making can offer an empirical grounding for the construct of competence, and therefore provide a useful mechanism for validating other, more expedient or context-specific measures of decision-making competence.

Additionally, the validity of such empirical measures of decision-making can be increased greatly by further research utilizing more relevant decision stimuli in a similar methodology. Finally, addressing the specific relationship between psychiatric symptoms, cognitive and verbal abilities, and different aspects of decision-making is necessary to clarify the complex set of cognitive functions subsumed under the heading of decision-making and their complex interactions with mental illness and psychopathology.

References


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